Evaluation of aerated lagoons performance and suggestion to develop more sustainable energy consumption in a STP plant; a case study

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***Abstract*— In this study, the process of a Sewage Treatment Plant (STP) in Marvdasht City, Iran, was reviewed to determine the efficiency of the two aerated lagoons each with 9 aerators. Major emphasize in this paper is on trying to address the parameters and treatment process in combination and eventually suggesting a more sustainable energy consumption in the STP. The focus of this study was to calculate the required oxygen with respect to BOD5, loading rate and other parameters. This allowed the determination of the aerator pump power ratings required to supply the oxygen was high and were found that by almost half of the present power consumption, the required oxygen level could still be achieved. To eliminate the adverse impact high energy consumption, the current and future decision-making in wastewater treatment should consider sustainability.**

Key words: sewage treatment plant, required oxygen, aeration lagoons, sustainable power consumption

I. Introduction

Aeration increases the dissolved oxygen (DO) concentration in water. With increased levels of oxygen available for microorganisms, biodegradation of organics occurs at a greater rate, increasing the treatment efficiency of a given system. An aerated lagoon also allows for reduction or elimination of odorous gases (hydrogen sulfide) and minimization of sludge production compared to non-aerated lagoons [1].

Aerated Lagoons are used in various parts of the world, especially in hot climates, for the treatment of biodegradable domestic and industrial sewage [2]. Aerated lagoons have considerable advantages over the traditional process of activated sludge, mainly for their low cost, operational simplicity and flexibility, besides the fact that they occupy a smaller area than the stabilization pond systems [3].

According to Sobrinho and Rodrigues [4], mixing is vital for the functioning of an aerated aerobic lagoon, in which the biomass is kept in suspension while the dissolved oxygen is evenly distributed into the water. In a surface-aerated system, the aerators provide two functions: they transfer air into the basins required by the biological oxidation reactions, and they provide the mixing required for dispersing the air and for contacting the reactants (that is, oxygen, wastewater and microbes). Biological oxidation processes are sensitive to temperature ranged between 0 °C and 40 °C. The rate of biological reactions increase with temperature and it is reported that most of surface aerated vessels operate at temperature between 4 °C and 32 °C [8].

In any STP plants, aerators provide oxygen and tend to be large consumers of electricity. Current and future engineering decision in a wastewater treatment should consider sustainability to ensure that humankind's use of natural resources does not have an adverse impact on the environment [5]. Considering that energy is one of the United Nation goals for sustainable development, in this study the major emphasize is to address all parameters and treatment process in combination to suggest more sustainable energy consumption in a STP plant.

II. Methodology

The selected STP in this study is situated in Marvdasht City located in the south central of Iran.

In this STP, there are two aerated lagoons each having total volumes of 21060 m^3 and working volume of 17550 m^3. Flow rate is 12000 m^3 per day. Organic loading rate is taken as 2940 kg/day of BOD. Theoretical hydraulic retention time of wastewater is about 3.6 days. In the studied STP, floating surface aerators are used in both aerated lagoons. Beychok [6] reported that ponds or basins using floating surface aerators achieve 80 to 90% removal of BOD with retention times of 1 to 10 days. The ponds or basins may range in depth from 1.5 to 5.0 meters. Each of the aeration lagoons has nine aerators and totally, there are 18 aerators to provide oxygen for the plant.

In this study, to acquire the optimal efficiency, the waste characteristics and important design parameters are reviewed. The system performance is assessed through the analysis of the following parameters: BOD5, COD, solid content, pH, temperature, dissolved oxygen, nitrates and phosphates. The STP plant serves a population of 50,000 and the first step in this study was collection of the supporting information about the characteristics of the wastewater, design dimensions and parameters of the lagoon as listed in Tables 1 and 2. In the second step according to the given dimensions of the lagoons and their design parameters in Tables 1 and 2, the following calculations were made:

1. Retention time in aerated lagoon (day) = [Klog (BOD in / BOD out)] [7a].

2. Loading rate (kg/day) =Total BOD / Flow rate

3. BOD removal.

4. Required oxygen (kg O_2/ kg BOD).

5. Actual power consumption in all the aeration turbines.

6. Power consumption in the turbines (KW/hr).

All the above mentioned calculations were made to find out if they correlated with the actual values of BOD, required oxygen and consequently the pump power needed for supplying required oxygen.

III. METHODOLOGY

For estimation of the efficiency of the aerated lagoons with respect to the power consumption, first the retention time, actual volume and operational volume of each lagoon were calculated. These parameters were computed based on the data presented in Tables I and dimension of the aerated lagoons presented in Table II.

TABLE I. DESIGN PARAMETERS.

Parameters	Inlet	Outlet
Max. flow (m^3/day)	12000	12000
BOD 5 (mg/litre)	245	35
TSS (mg/litre)	169	85
COD (mg/litre)	384	73.5
BOD loading rate	2940 kg/day	-
Mean temperature (ºC)	18	21
DO (mg/litre)	0.49	1.97
pH	7.58	8.29

TABLE II. DIMENSION OF AERATION LAGOONS.

Dimensions	Unit	value
Length	m	90
Width	m	90
Depth	m	3
Operational depth	m	2.5
Side slope	-	1:3
Surface area of each lagoon	m²	7600

a. The number of the aeration lagoon= 2, The shape of the two aeration lagoons was trapezoid.

Based on the design criteria and lagoons dimension the retention time, operational and total volume were calculated as presented in Table III and IV. It was find out the retention time was 2.004 and1.6 days for lagoon 1 and 2 respectively.

Figure 1 shows the plan of first and second aeration of lagoon that are situated in sequence and signed in a red frame.

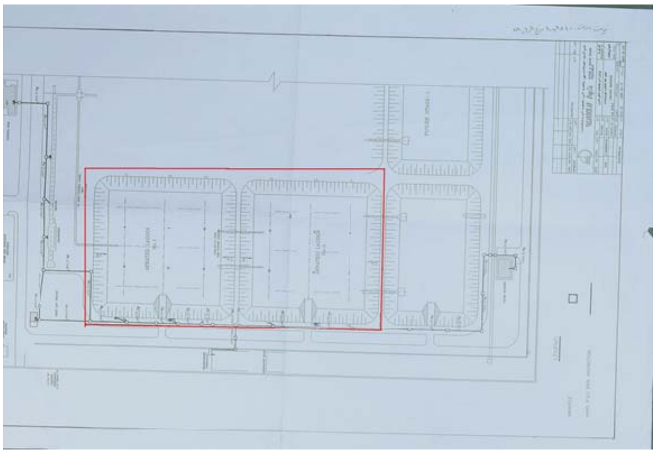

Fig. 1. Schematic figure of aeration lagoons marked with a red frame.

TABLE III. CALCULATION FOR THE FIRST AERATION LAGOON

Criteria	unit	Value
Retention time	day	K. log (BOD in / BOD out)= 0.8 log (245/122.5)= 2.004 where K = Oxygen transfer factor [7a]
Total volume	m³	21060
Operational volume	m³	17550

TABLE IV. CALCULATION FOR THE SECOND AERATION LAGOON

Criteria	unit	Value
Retention time	day	K. log (BOD in / BOD out)= 0.8 log (122.5 / 48.9)= 1.6 where K = Oxygen transfer factor [7a]
Total volume	m³	21060
Operational volume	m³	17550

Based on the dimensions, design criteria and calculated related criteria the require oxygen was calculated to be 90.35 and 27.78kg/hr in the first and second lagoon respectively (Table III and IV).

TABLE V. THE REQUIRED OXYGEN IN THE AERATION LAGOONS WERE CALCULATED AS FOLLOWS .

Detail	Unit	Value
Flow	m³/ day	12000
Total BOD removed in first lagoon	Kg/ m³	BOD in- BOD out/1000=0.139
Loading rate removal in first lagoon	Kg/day	BOD removal x flow=1668
Oxygen requirement in the first lagoon	Kg/hr	1668x 1.3 /24*=90.35 *kg oxygen per kg BOD removed [7b]
Total BOD removed the in second lagoon	Kg/ m³	BODin-BODout/1000=0.0428
Loading rate removed in the second lagoon	Kg/day	0.0428/12000= 513.6
Oxygen requirement in the second lagoon	Kg/hr	513.6 x 1.3 /24*=27.78 * kg oxygen per kg BOD removed [7b]

The aeration system in this STP is a high-speed surface aerated system with the oxygen transfer capacity of 0.7 kg/ KW-hr [7_c]. The calculation of the power consumption in each lagoon was done as follows;

TABLE VI. POWER CONSUMPTION IN THE FIRST AERATION LAGOON.

Detail	Unit	Value
Power of each aerator	KW hr	20
Actual Power consumption of the aerators	KW hr	20 x 9 = 180
Volume	m^3	17550
Mixing requirement	KW hr	*1.2 x 17550/1000= 21.06 *Threshold energy input value for the suspension of biosolids in KW/10^3 m^3[7_d]
Oxygen requirement	Kg/ hr	90.35
Power consumption for the oxygen transfer capability	KW hr	90.35/ 0.7=129.06
Total required power consumption	KW hr	129.06+21.06=160.12

TABLE VII. POWER CONSUMPTION IN THE SECOND AERATION LAGOON.

Detail	Unit	Value
Power of each aerator	KW hr	20
Actual Power consumption by the aerators	KW hr	20 x 9 = 180
Volume	m^3	17550
Mixing requirement	KW hr	1.2x 17550/1000= 21.06
Oxygen requirement	Kg/ hr	27.78
Power consumption for the oxygen transfer capacity	KW hr	27.78/ 0.7=39.68
Total required power consumption	KW hr	39.68+21.06=60.74

Figure 2 shows the actual power consumption of each aeration lagoon by comparing it with the real required power as found through cited calculation. It was found that there was an extra power consumption of 19.88 (KWhr) and 119.26 (KWhr) in the first and second aeration lagoons, respectively. The extra total power consumption would be 138.55 KW hr for all 18 pumps in the two aeration lagoons.

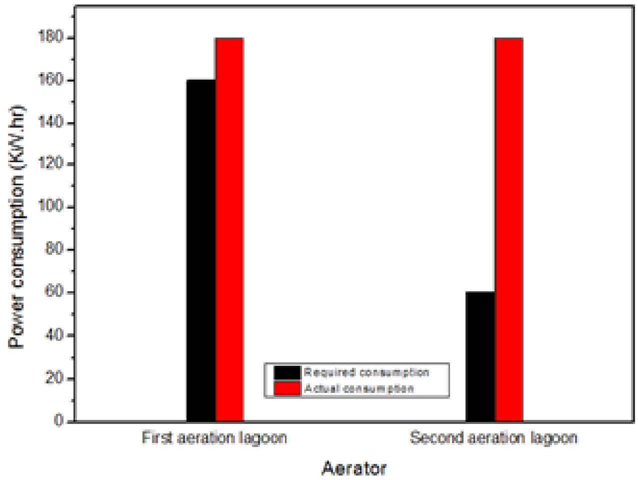

Fig. 2. Comparison between required and actual power consumption of each aerator.

IV. CONCLUSION

Existing aerated lagoons in a domestic wastewater treatment plant were studied to determine organic removal and coefficient of oxygen consumption and consequently power consumption.

The whole operation units of this STP were reviewed. It was found that the aeration lagoons were a complete and low-priced system for treatment of wastewater of small communities with the BOD5 removal of 80.3%. But based on the results of BOD5, loading rate, mean temperature and depth of the aeration lagoons, it could be concluded that the aerators could have the same function with the less consumed power supply. Therefore, eefficient treatment capacity of the lagoons would be possible with reducing the power supply of the aerators in the given system.

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